Building Robust Cellular Networks

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Based on "The Urge to Merge: When Cellular Providers Pool Capacity," by Sha Hua, Pei Liu and Shivendra S. Panwar, Proceedings of the IEEE ICC, 2012.

What happens when operators cooperate for business reasons *or after a disaster?*

☐ Example (US): AT&T merger attempt with T-Mobile *and the recent temporary AT&T T-Mobile "merger" after Sandy*

☐ Other examples (Europe): Vodafone and O2(Telefonica) in the UK (June 7, 2012), Telenor and Tele2, O2 and Eplus (Germany)

- Share infrastructure *or share surviving infrastructure*
- Share spectrum
- Increase capacity *or maintain capacity*
- Lower OPEX and CAPEX *or reduce vulnerability*
- Better service to users *or maintain capacity*
- Larger revenue and profitability *or improve reliability*

□ **Traditional Roaming**

● Only works when no connection available to the assigned operator
   (e.g. connect to AT&T when the signal from T-Mobile is weak or non-existent)

● Stringent constraints and high charges

□ **Extending the roaming concept**

One scenario is that the users can freely access the BSs of either operator by the "strongest signal-first" rule

The principle of increased service through sharing can be extended to a neighborhood femtocell "connectivity island" based on subscribers with backup power supplies and functioning ISP's. This assumes femtocells can at least temporarily be opened to subscribers to competing carriers.

Hexagonal Layout Example

Without Cooperation

- Edge users such as those at points B, D and F of Operator 1 will experience poor channel conditions and strong inter-cell interference.

Operator 1
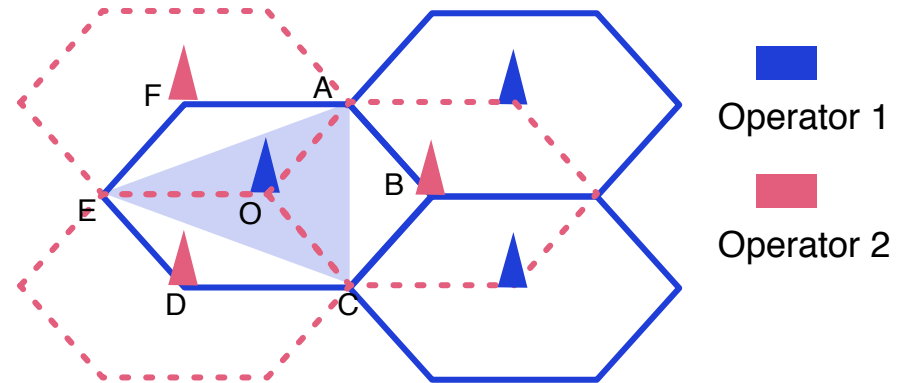
Operator 2

With Cooperation

- Users at B, D and F will be served by the BSs of Operator 2 and have excellent channels.
- Generally, the users of Operator 1 in the triangles ABC, ECD and EFA will enjoy performance gains. Similar effect happens to users of Operator 2 as well.
- **Capacity is quadrupled, per customer capacity is doubled**

Two Cooperation Strategies

- **FLEXROAM** (short for "Flexible Roaming")

Cellular operators allow their users to freely connect to any BS of the operator that provides the best signal strength. An update in signaling protocols is required to facilitate this.

- **MERGER**

In addition to FLEXROAM, *operators fully share their spectrum as well*. This could be a business agreement short of a full merger, e.g., MVNO, or temporarily during a man-made or natural disaster
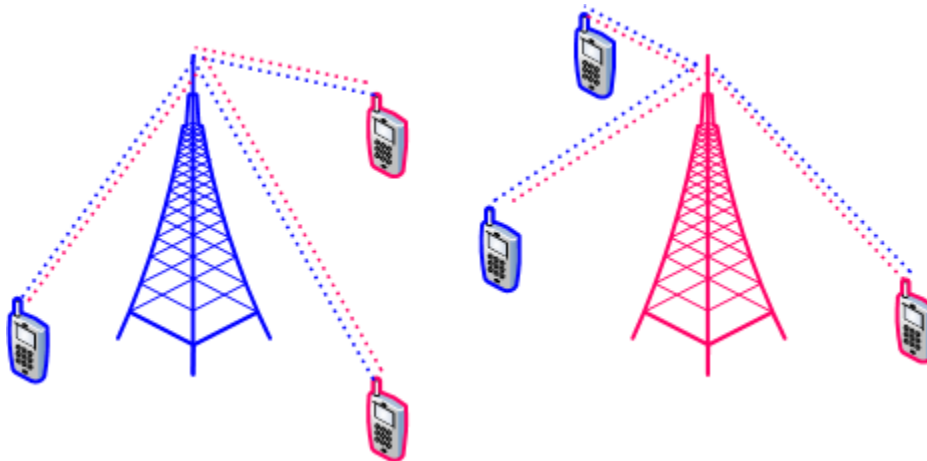
Average User Rate/Throughput

- **Analytical Modeling**

Based on stochastic geometry, provides tractable and reasonably accurate results.
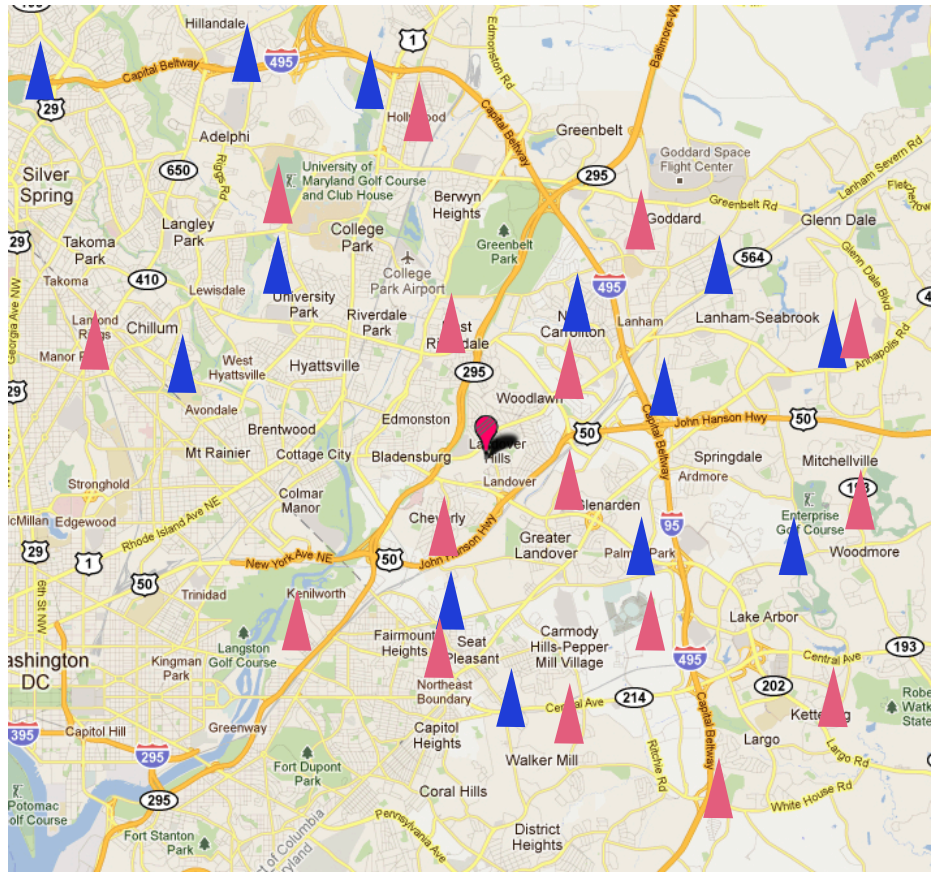
- Assumes Poisson random BS deployment;

- Uses the entire spectrum without sub-channelization;

- Assumes perfect resource allocation following the proportional fairness criterion

- **Simulation**

Monte-Carlo simulations

- Use real BS location data

- OFDMA scheduling algorithm

Real BS Location Information

Precise coordinates of BSs from two major operators over 20 x 20 km suburban area near Washington D.C.

MAIN CONCLUSION:

- Simple cooperation policy with modest changes to existing networks achieve large capacity gain. (FLEXROAM: 45%, MERGER: 100%)

- Network capacity after MERGER of two identical carriers *quadruples* the capacity as compared to a single operator

FUTURE WORK:

- **More cooperation strategies**. e.g., leveraging relay stations/ mobile devices to forward the traffic, multi-cell cooperation, etc.

- **Load balancing** and **energy efficiency**.

- **Pricing**: Using Game Theory to analyze how to achieve a fair solution and how to share the profits or costs.

Thanks

Q & A